

## Claims

We claim:

1. A system that enforces currency constraints on a query on a database system having a query optimizer, a query processing engine and one or more local replicas of data in remote data sources comprising:

a constraint parser that interprets and converts the currency constraint into a form usable by the query optimizer;

a query plan generator that constructs a query plan for executing the query, wherein the plan includes one or more subplan selection operators that check a currency of a local replica against the query's currency constraint and selects the subplan using the local replica only when the constraint is met; and

wherein the query processing engine executes the query plan, including the subplan selection operators, thereby producing a result that satisfies the query's currency constraints.

2. The system of claim 1 comprising a currency constraint normalizer that resolves a plurality of currency constraints into a single constraint representing a least upper bound of the currency constraints.

3. The system of claim 1 wherein tables in the local replica are grouped into currency regions and wherein the data in all tables in a currency group correspond to the same database state.

4. The system of claim 3 comprising a heartbeat mechanism that includes a global heartbeat table and local replicated heartbeat tables that keep track of the currency of local replicas.

5. The system of claim 4 wherein the data source selection operator accesses a local heartbeat table to determine whether the currency of local replica meets the currency constraint.

6. The system of claim 1 wherein the query optimizer estimates a cost associated with a query plan to be executed using a local replica based on a probability that the local replica will meet the currency constraint of the query.

7. The system of claim 1 wherein the currency constraints includes a consistency constraint and wherein the constraint parser parses the consistency constraint.

8. The system of claim 7 wherein the query plan generator verifies possible query plans against the query's consistency constraint and rejects plans that do not meet the consistency constraint.

9. The system of claim 7 comprising a consistency constraint normalizer that resolves a plurality of consistency constraints into a single consistency constraint representing a least upper bound of the constraints.

10. The system of claim 7 comprising a mechanism for enforcing timeline consistency constraints that appends a query's currency constraint with an additional session-specific currency bound specifying that the query's input data must reflect a database state later than or equal to the latest database state of any input used by designated prior queries within the same session.

11. The system of claim 8 wherein the query plan generator derives a delivered consistency property for each plan based on physical operators in the plan and compares the delivered consistency with the query's consistency constraint.

12. The system of claim 8 wherein local replicas are grouped into currency regions and wherein the query plan generator verifies that all inputs in a query plan that must be consistent belong to the same currency region.

13. A method for specifying and enforcing currency and consistency requirements associated with a database query, comprising:
- parsing a currency and consistency constraint to interpret and convert the constraint into a form usable by a query optimizer;
  - constructing query execution plans that include a subplan selection operator that verifies a currency of a local replica against the query's currency constraint and selects the subplan using the local replica only when the local replica's data meets the currency constraint;
  - verifying the query execution plans against the query's consistency constraints and rejecting any plans that do not meet the consistency constraint; and
  - executing the query plan, including any subplan selection operators, thereby producing a result that satisfies the query's currency and consistency constraints.
14. The method of claim 13 comprising resolving a plurality of currency and consistency constraints associated with the database query into a single currency and consistency constraint that represents a least upper bound of the constraints.
15. The method of claim 14 comprising grouping local replicas into currency regions wherein the data in all replicas within a currency region always reflect the same database state.
16. The method of claim 15 comprising utilizing a heartbeat mechanism to maintain a global heartbeat table and local replicated heartbeat tables that keep track of the currency of local replicas.
17. The method of claim 16 wherein the subplan selection operator refers to information in a log to verify the currency of the local replica.

18. The method of claim 15 wherein possible query plans are evaluated by determining a delivered consistency based on physical operators in the query plan that group input tables into sets of consistent input tables and verifies that the input tables in a set of consistent input tables belong to the same currency region.

19. The method of claim 13 comprising estimating a cost associated with a query plan to be executed using a local replica based on a probability that the local replica will meet the currency constraint of the query.

20. Computer-readable media comprising computer-executable instructions for performing the method of claim 13.

21. For use with a database system, computer readable media comprising computer-executable instructions for enforcing currency constraints on a query on the database system, wherein the database system has local replicas of data in remote data sources, the instructions comprising:

interpreting and converting the currency constraint into a form usable by a query optimizer;

constructing a query plan for executing the query, wherein the plan includes a subplan selection operator that checks a currency of a local replica against the query's currency constraint and selects the subplan using the local replica only when the constraint is met; and

executing the query plan, including the subplan selection operators, thereby producing a result that satisfies the query's currency requirements.

22. The computer readable media of claim 21 wherein the instructions comprise resolving a plurality of currency constraints into a single constraint that represents a least upper bound of the currency constraints.

23. The computer readable media of claim 21 wherein the instructions comprise grouping local replicas into currency regions and wherein the data in all replicas within a currency region always reflect the same database state.

24. The computer readable media of claim 23 wherein the instructions comprise utilizing a heartbeat mechanism to maintain a global heartbeat table and local replicated heartbeat tables that track the currency of local replicas.

25. The computer readable media of claim 24 wherein the subplan selection operator accesses a local heartbeat table to determine whether the currency of local data source meets the currency constraint.

26. The computer readable media of claim 21 wherein the instructions comprise estimating a cost associated with a query plan to be executed using a local replica based on a probability that the local replica will meet the currency constraint of the query.

27. The computer readable media of claim 21 wherein the currency constraints include a consistency constraint and wherein the instructions comprise parsing the consistency constraint.

28. The computer readable media of claim 27 wherein the instructions comprise verifying possible query plans against the query's consistency constraint and rejecting plans that do not meet the consistency constraint.

29. The computer readable media of claim 28 wherein the instructions comprise resolving a plurality of consistency constraints into a single consistency constraint that represents a least upper bound of the constraints.

30. The computer readable media of claim 27 wherein the instructions comprise deriving a delivered consistency property for each plan based on physical operators in the plan and comparing the delivered consistency with the query's consistency constraint.

31. The computer readable media of claim 28 wherein the instructions comprise grouping local replicas into currency regions and verifying that all inputs in a query plan that must be consistent belong to the same currency region.

32. An apparatus for specifying and enforcing currency and consistency requirements associated with a database query, comprising:

means for interpreting and converting the currency constraint into a form usable by a query optimizer;

means for constructing a query plan for executing the query, wherein the plan includes a subplan selection operator that checks a currency of a local replica against the query's currency constraint and selects the subplan using the local replica only when the constraint is met; and

means for executing the query plan, including the subplan selection operators, thereby producing a result that satisfies the query's currency requirements.

33. The apparatus of claim 32 including means for resolving a plurality of currency constraints into a single constraint that represents a least upper bound of the currency constraints.

34. The apparatus of claim 32 comprising means for grouping local replicas into currency regions and wherein the data in all replicas within a currency region always reflects the same database state.

35. The apparatus of claim 34 wherein the means for grouping utilizes a heartbeat mechanism to maintain a global heartbeat table and local replicated heartbeat tables that track the currency of local replicas.

36. The apparatus of claim 35 wherein the subplan selection operator accesses a local heartbeat table to determine whether the currency of local data source meets the currency constraint.



37. The apparatus of claim 32 comprising means for estimating a cost associated with a query plan to be executed using a local replica based on a probability that the local replica will meet the currency constraint of the query.

38. The apparatus of claim 32 wherein the currency constraints include a consistency constraint and comprising means for interpreting and converting the consistency constraint.

39. The apparatus of claim 38 comprising means for verifying possible query plans against the query's consistency constraint and rejecting plans that do not meet the consistency constraint.

40. The apparatus of claim 39 comprising means for resolving a plurality of consistency constraints into a single consistency constraint that represents a least upper bound of the constraints.

41. The apparatus of claim 38 comprising means for deriving a delivered consistency property for each plan based on physical operators in the plan and comparing the delivered consistency with the query's consistency constraint.